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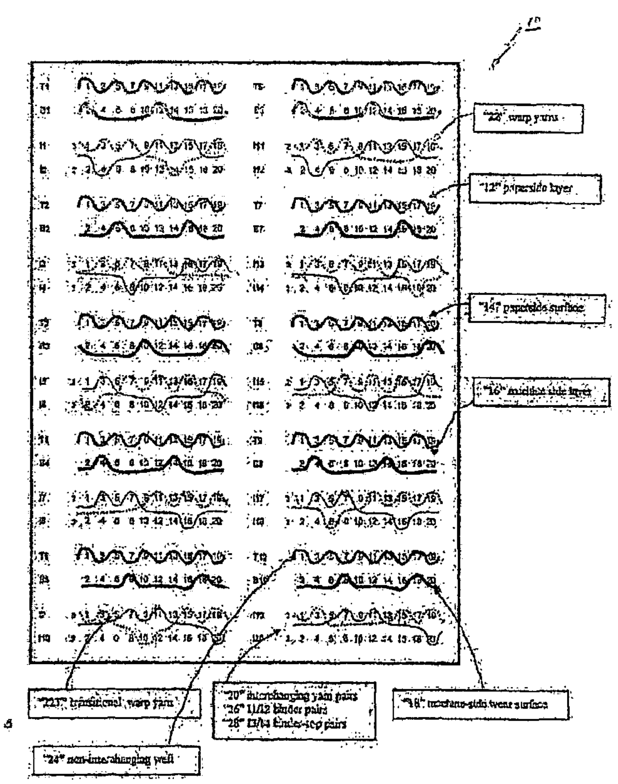
(54) Title: A COMPOSITE FORMING FABRIC



(57) **Abstract:** A composite forming fabric comprising a paper side layer having a paper side surface, a machine side layer having a bottom wear side surface, and a plurality of pairs of first and second interchanging yarns, wherein: the paper side layer and the machine side layer each comprise warp yarns and weft yarns woven together; said paper side layer and said machine side layer each having a predetermined repeat of the weave pattern in the cross-machine-direction; each pair of first and second interchanging yarns having at least two segments in the paper side layer within each repeat of the weave pattern, said segments providing an unbroken weft path in the paper side surface, with each succeeding segment being separated in the paper side surface of the paper side layer by at least one paper side layer transitional warp yarn; at least one pair of first and second interchanging yarns within each repeat of the weave pattern being binder yarn pairs, each binder yarn in each binder yarn pair binding together the paper side layer and the machine side layer, and at least one pair of first and second interchanging within each repeat of the weave pattern being top weft/binder yarn pairs for stiffening the fabric and binding together the paper side layer and the machine side layer of the fabric.

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A COMPOSITE FORMING FABRIC

FIELD OF THE INVENTION

The present invention relates to fabrics with paired, interchanging yarns, and more particularly, to fabrics employed in web forming equipment, such as papermaking and non-woven web forming equipment. More particularly, the preferred fabrics of this invention are employed as forming fabrics in web forming equipment.

BACKGROUND OF THE INVENTION

Papermaking involves the forming, pressing and drying of cellulosic fiber sheets. The forming process includes the step of depositing an aqueous stock solution of the fibers, and possibly other additives, onto the forming fabric upon which the initial paper web is formed. The forming fabric may run on a so-called Gap Former machine in which the aqueous stock initially is dewatered, and the initial paper sheet is formed between two forming fabrics.

An effective forming process typically produces a sheet with a very regular distribution of fibers and with a relatively high solids content, i.e., a high fiber-to-water weight ratio. In order to form a fibrous web with a desired uniform, regular distribution and high fiber-to-water weight ratio, the forming fabric must possess a number of properties. First, the papermaking surface should be relatively planar; resulting from the yarn floats in both the machine direction (MD) and cross-machine-direction (CD) lying at substantially the same height, to thereby prevent localized penetration of the fibers into the fabric. Such localized penetration results in "wire marks" which actually is the result of fiber density variations throughout the sheet area. In addition, the MD and CD floats need to be distributed in a regular manner to avoid introducing undesired wire marks into the formed sheet. Moreover, these basis weight variations can result in undesired variations in sheet absorption properties; a property very relevant to the functionality of

quality graphical papers where a consistent uptake of print ink is necessary to produce a clear sharp image.

Other factors also cause the formation of undesired wire marks. For example, wire marks can be introduced into the sheet by the flow of water around yarns positioned below the fabric's papermaking surface. This phenomena, referred to as "strike through" needs to be taken into account in designing the fabric construction.

Importantly, the forming fabric must also possess a high degree of dimensional stability. This high stability is necessary, for example, to minimize cyclic variations in fabric width, which can result in MD wrinkles in the fabric. This, in turn, contributes to the so-called, streaky sheet, i.e., a sheet with machine direction streaks created by variations in fiber density.

Dimensional stability of a fabric typically is obtained by manufacturing the forming fabric with a relatively high mass of material. However, the use of thick yarns often causes undesirable wire marks. Consequently, there has been a trend to providing composite forming fabrics, that is, "multi-layer" structures, whereby a high number of relatively thin yarns are distributed throughout various fabrics layers to facilitate fabric stability.

One type of multi-layer structure is a triple-layer fabric made by joining two (2) distinct fabrics, each with their own machine direction (warp) yarns and cross-direction (weft) yarns, by the use of additional and independent "binding yarns." These binding yarns can be employed in either the machine direction or cross-machine-direction, and in this system provide the sole function of binding the two separate fabrics together. In other words, these binding yarns are not intended to function as part of the warp or weft yarn system in either the top fabric or the bottom fabric of the multi-layer structure. Such a triple-layer fabric is illustrated in EP 0,269,070(JWI Ltd.).

Where the two fabrics of the triple-layer structure are joined in either the machine direction of cross-machine-direction by binding yarns that also belong, or form part of the weave pattern of either, or both, of the paper side or wear side fabrics, the resulting structures are referred to more specifically as "self-stitched" triple-layer structures. Such binding yarns are referred to as intrinsic binding yarns. Self-stitched structures are taught in a number of prior art patents. For example, U.S. Patent No. 4,501,303 (Nordiskafilt AB) discloses a triple-layer structure wherein paper side yarns are used to bind the paper side and wear side fabrics into one structure.

Triple-layer structures, whether employing separate and distinct binding yarns or intrinsic binding yarns that form part of the paper side and/or wear side weave structure, allow, to some extent, for the use of fine machine direction and cross-machine-direction yarns in the paper side fabric layer for improved papermaking quality and sheet release. Additionally, the use of significantly coarser yarns can be employed in the lower fabric layer, or wear side fabric layer, which contacts the paper machine elements, to thereby provide good stability and fabric life. Thus, these triple-layer structures have the capability of providing optimum papermaking properties in the paper side fabric layer and optimum mechanical properties in the wear side fabric layer.

In the triple-layer and self-stitched fabrics of the prior art there is typically contact between the internal surfaces of the paper side and wear side fabric layers. The internal surface of the wear side fabric layer is dominated by floats of machine direction yarns in all known commercial embodiments of the triple-layer and self-stitched fabrics. Where wear side fabric cross-direction yarns interlace with wear side fabric machine direction yarns, such that the wear side cross-direction yarns appear in the internal region between the paper side and wear side fabric layers, relatively prominent short weft knuckles are formed. The pressure of relatively stiff wear side machine direction yarns acting on the wear side cross-direction yarns during the production of the fabric can cause so-called "knuckle spread," whereby the wear side cross-direction yarn knuckles are distorted and their width increased to form a relatively large area. It has been found that fibrous sheet areas formed on the paper side fabric above such knuckles are

noticeably different in appearance from adjacent sheet areas. Such sheet differences can contribute to variations in the quality of print imparted to the fibrous sheet in a subsequent printing step.

A further common feature of the known self-stitched and other triple-layer designs is that they are relatively thick structures with a high amount of empty space distributed throughout their thickness. The relatively high "void volume" is typically associated with sheet rewetting on the paper machine such that the sheet solids content at transfer to the press section may be undesirably low. That is, the fibrous web formed on the papermaking fabric has an undesirably low fiber-to-weight ratio. This can result in reduced papermaking machine performance through a higher amount of sheet breaks, reduced running speed and higher drying costs downstream of initial web formation.

U.S. Patent No. 4,636,426, discloses a relatively thin, forming fabric with reduced rewetting potential. Specifically, this forming fabric includes two adjacent, monofilaments strands of conventional circular cross-section glued together using a heat-activated polymeric adhesive. The joined cylindrical strands are utilized in either or both of the machine and cross-direction yarns of the fabric. The adhesive also is used to adhere the machine direction and cross-direction yarns at their cross-over points. By this means yarns of smaller than normal diameter can be used to thereby reduce the overall height of the fabric. However, fabrics formed in the above way have the disadvantage that an additional gluing process is required which adds to the manufacturing cost of the fabric. Moreover, the results may not be permanent, in that the fabrics are susceptible to separation of the joined (glued or fused) yarns. Additionally, the reduction in yarn mass, compared with prior art structures of the type disclosed in the U.S. Patent No. 4,636,426, may result in reduced fabric stability.

A variety of compromise fabrics employing intrinsic interchanging yarn pairs have been disclosed to attempt to deal with the various problems of fabric strength, fabric stability, e.g., fabric stiffness, desired papermaking side performance and desired wear side performance. In particular, various different composite fabric constructions are

disclosed in U.S. Patent Nos. 4,501,303 (Osterberg); 5,152,326 (Voehringer); 5,826,627 (Seabrook, et al.); 5,967,195 (Ward) and International Publication WO 02/14601 A1 (Andreas Kufferath GMBH&Co. KG).

Although the aforementioned composite papermaking fabrics employing intrinsic interchanging yarn pairs have provided improved structures, applicant believes that there still is a need for additional, improved composite structures of the type employing intrinsic interchanging yarn pairs having improved properties, such as reduced sheet marking potential and/or longer service life potential and/or higher resistance to layer delamination. It is to such structures that the present invention is directed.

SUMMARY OF THE INVENTION

The above and other objects of this invention are obtained in composite forming fabrics having a paper side layer with a paper side surface, a machine side layer having a bottom wear side surface and a plurality of pairs of first and second intrinsic interchanging yarns. Reference throughout this application to "intrinsic interchanging yarns" or "interchanging yarns" means yarns that form a part of the weave structure in at least the paper side layer of the composite fabric.

In accordance with a first preferred embodiment of this invention, the paper side layer and the machine side layer each comprise machine direction warp yarns and non-interchanging cross-machine-direction weft yarns woven together; said paper side layer and said machine side layer each having a weave pattern in the cross-machine direction with a predetermined repeat; each pair of first and second interchanging yarns having at least two (2) segments in the paper side layer within each repeat of the weave pattern, said segments providing an unbroken weft path in the paper side surface, with each succeeding segment being separated in the paper side surface of the paper side layer by at least one paper side layer transitional warp yarn; at least one pair of first and second interchanging yarns within each repeat of the weave pattern being intrinsic top

weft/binder yarn pairs for stiffening the fabric and binding together the paper side layer and the machine side layer of the fabric.

The transitional warp yarn defines the length of each segment made in the paper side layer of the fabric by each individual yarn of an interchanging yarn pair. Specifically, one yarn of each pair forms a segment of the paper side weft path and then drops out of the paper side surface adjacent one side of the transitional warp yarn, while the other yarn of the pair moves into the paper side layer adjacent the opposite side of the transitional warp yarn to begin forming a second segment of the paper side weft path.

"Intrinsic weft binder yarns" are weft yarns that are part of the weave structure of the paper side surface of the paper side layer and also serve to bind together the paper side layer and machine side layer within each repeat of the weave pattern. Thus, each intrinsic weft binder yarn of each pair of first and second intrinsic weft binder yarns provides two functions within each repeat of the weave pattern. One function is to contribute to the weave structure of the paper side surface of the paper side layer, and the second function is to bind together the paper side layer and the machine side layer.

Each intrinsic weft binder yarn within each pair of interchanging yarns forms the weft path in at least one segment of the paper side layer within each repeat of the weave pattern, and then disappears from the paper side surface at a transitional warp yarn by dropping down to engage at least one warp yarn in the machine side layer underlying another segment within each repeat of the weave pattern to thereby bind the machine side layer to the paper side layer. With respect to the intrinsic binder yarn pairs employed in this embodiment of the invention, one yarn forms part of the weft path in a segment of the paper side layer within each repeat of the weave pattern that is not occupied by the other yarn of the intrinsic weft binder yarn pair, and then drops down to engage at least one warp yarn of the machine side layer in a region underlying the other intrinsic weft binder yarn which is forming another segment of the weft path of the paper side layer. In other words, within each repeat of the weave pattern, each of the weft binder yarns within each pair of intrinsic weft binder yarns contributes to the weft path in

the paper side surface in at least one segment of the repeat and also drops down to engage at least one machine direction yarn in the machine side layer in a region underlying a different segment within said repeat of the weave pattern.

In a composite fabric structure including two segments in the paper side layer within each repeat of the weave pattern, one of the intrinsic weft binder yarns within each pair of binder yarns provides a weft path in the paper side surface in one segment while the second intrinsic weft binder yarn of the pair engages at least one machine direction warp yarn in the machine side layer underlying said one segment, and said first intrinsic weft binder yarn then moves out of the paper side layer and into the machine side layer to engage at least one machine direction warp yarn of the machine side layer in the second segment within each repeat of the weave pattern and said second intrinsic weft binder yarn moves up into the second segment of the paper side layer to continue the weft path in the cross-machine-direction of the paper side fabric layer.

Most preferably the segments in the paper side layer formed by pairs of interchanging yarns within each repeat of the weave pattern provide an unbroken weft path in the paper side surface, with each succeeding segment being separated in the paper side surface of the paper side layer by at least one paper side layer transitional warp yarn. This latter arrangement of intrinsic binder yarn pairs in a weave pattern having only two segments in the paper side layer is disclosed in Seabrook et al., U.S. Patent No. 5,826,627, the subject matter of which is herein fully incorporated by reference. It should be understood that in the structures disclosed in the Seabrook et al., '627 patent, all of the interchanging weft yarn pairs are binder yarn pairs and the disclosed papermaking fabrics include only two segments in the paper side layer within each repeat of the weave pattern.

Reference throughout this application to "intrinsic top weft/binder yarn pairs" means a pair of yarns wherein one yarn of the pair; namely the binder yarn of the pair, forms the weft path in the paper side surface of the paper side layer in at least one segment of each repeat of the weave pattern and then drops down to encircle at least

one warp yarn in the machine side layer in a region underlying at least another segment within each repeat of the weave pattern in the paper side layer. The weft yarn of the weft/binder yarn pair forms the weft path in a segment in the paper side layer within each repeat of the weave pattern that is not occupied by the binder yarn of the pair, and then drops our of the paper side layer to float between the paper side layer and machine side layer in one or more other segments within each repeat of the weave pattern; without in any way binding the paper side layer to the machine side layer. A "top weft/binder yarn pair" is illustrated in Fig. 2(b) of International Publication No. WO 02/14601, the subject matter of which is incorporated herein by reference.

In a preferred embodiment of this invention the fabric includes a plurality of intrinsic interchanging binder yarn pairs and a plurality of intrinsic, interchanging top weft/binder yarn pairs. In a preferred embodiment of this invention at least 50% of the interchanging yarn pairs are intrinsic interchanging top weft/binder yarn pairs.

In one preferred embodiment of this invention alternate top weft yarns are provided by interchanging yarn pairs; with alternate pairs being binder yarn pairs and the other alternate pairs being top weft/binder yarn pairs. Thus, in this preferred embodiment, 50% of the top weft yarns are formed by interchanging yarn pairs, with 50% of such interchanging yarn pairs being binder yarn pairs and the other 50% of such interchanging yarn pairs being intrinsic top weft/binder yarn pairs.

In a further embodiment of this invention, the composite fabric, in addition to including at least one pair of intrinsic, interchanging binder yarn pairs and at least one pair of intrinsic interchanging top weft/binder yarn pairs, also includes at least one pair of intrinsic interchanging weft yarn/weft yarn pairs.

As used throughout this application, reference to "weft yarn/weft yarn" in referring to a pair or pairs of yarn(s) refer(s) to a pair of intrinsic interchanging yarns wherein each yarn forms the cross direction weave path in alternate segments of the paper side surface and then drops down to float between the paper side layer and the machine side

layer in the remaining segments within the repeat, and then, after floating between the paper side layer and machine side layer, moves back into the paper side layer to provide a continuation of the weft path in the fabric. One yarn of the weft yarn/weft yarn pair floats between the paper side layer and the machine side layer in a region underlying the segment in which the other weft yarn of the pair forms the weft path in the paper side surface, and then moves up into the paper side surface in an adjacent segment to form the weft path in that segment of the paper side surface overlying the portion of the other weft yarn of the pair that has moved out of the paper side layer to float between the paper side layer and machine side layer in such adjacent segment. Thus, in this embodiment the weft yarn/weft yarn pair cooperates to provide a continuous unbroken weft path across the paper side surface and also includes segments that float between the paper side layer and the machine side layer to stiffen the fabric. Neither yarn of the weft yarn/weft yarn pair cooperates to bind the paper side layer and the machine side layer together.

In accordance with this invention, segments within each repeat of the weave pattern may have different lengths, if desired. That is, one weft yarn of a pair of interchanging yarns interlaces with a number of adjacent top warp yarns in one segment that is different from the number of adjacent top warp yarns that interlace with the other weft yarn of the pair in another segment within each repeat of the weave pattern.

In one form of the invention, the paper side layer and the machine layer together are woven in a predetermined number of sheds to provide the repeat pattern of the composite fabric. For example, a twenty (20) shed fabric includes ten (10) machine direction warp yarns in the paper side layer and ten (10) machine direction warp yarns in the machine side layer vertically underlying machine direction warp yarns in the paper side layer.

In accordance with certain embodiments of the invention at least some of the binder yarns in the pairs of first and second intrinsic, interchanging yarns float under at least two adjacent wear side machine direction yarns, and if desired, under at least three

adjacent wear side machine direction yarns to provide enhanced binding of the paper side layer to the machine side layer.

In addition, by floating the interchanging yarns under two or more adjacent wear side machine direction yarns, the overall height and void volume within the fabric is reduced. This reduces the potential water carrying potential of the fabric; resulting in the formation of a dryer sheet on the fabric.

In an alternative structure for providing a thin fabric with minimal delamination tendency at least some of the binder yarns of the interchanging binder yarn pairs interlace with a number of single, non-adjacent wear side MD yarn within each repeat of the weave pattern.

In all embodiments of the invention disclosed herein all or some of the wear side and/or paper side warp yarns can be of a non-circular cross section but particularly of bi-nodal (e.g., dumbbell - or "figure 8" shaped) cross-section. The bi-nodal yarn(s) is (are) extruded with the bi-nodal cross section and thus require(s) no bonding process of the type employed in the prior art, where two adjacent, but separately-formed warp yarns have been woven to an identical weave repeat. Use of bi-nodal warps, with a vertical-to-horizontal aspect ratio of at least 1:1.25, allows a thinner fabric to be provided but with the same overall cross sectional area as prior art structures. This will reduce the water carrying capacity of the fabric, thereby resulting in the formation of a paper sheet with reduced moisture content in the forming section, which, in turn, reduces production costs. Furthermore, unlike the use of profiled and flat warp yarns employed in prior art forming fabrics, the bi-nodal yarns employed in this invention provide several benefits as follows: (1) each bi-nodal yarn provides a drainage channel along the center thereof to effectively direct water through the fabric; (2) the use of bi-nodal yarns avoids the single large surface of the prior rectangular and ovate yarns, which could directly or indirectly undesirably mark the sheet; (3) when used as a wear side warp the bi-nodal yarn is less likely to cause as severe a distortion of the interlacing weft yarn knuckles as a yarn of similar cross-sectional area but of a circular cross section to thereby potentially cause

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less strike-through marking of a paper sheet formed thereon and (4) when used in the fabric paper side layer in the same number as prior art, circular cross-section yarns the bi-nodal yarn will double the MD orientated fiber support points of the fabric due to the two, generally circular, dumbbell shaped ends forming part of each bi-nodal yarn; thereby reducing, or minimizing the formation of undesired wire-marks in the formed paper sheet.

In accordance with another aspect of this invention, the binder position relative to the interlacings of the warp and weft yarns in the wear side layer of the fabric can be selected to facilitate a significant increase in fabric bending stiffness and thus the ability of the fabric to control sheet basis weight profiles in a desired manner.

The embodiments of the invention illustrated herein typically have 2:1 ratio of paper side layer cross-machine-direction weft paths to wear side cross-machine-direction weft paths. However, it is within the scope of this invention to provide different ratios of paper side layer CD weft paths to wear side layer CD weft paths, such ratio being dictated by the desired use of the fabric. For example, and not by way of limitation, it is within the scope of this invention to employ paper side layer to machine side layer CD weft path ratios of 1:1, 3:2, 4:3, or another ratio.

Although the preferred embodiments of this invention include non-interchanging weft yarns in the paper side layer, it is within the scope of this invention to form the paper side layer with warp yarns and only interchanging CD yarn pairs.

Although the preferred embodiments of the inventions employ a paperside to wearside warp ratio of equal number, specifically 1:1, it is also envisaged that all embodiments can be manufactured with a different warp ratio, e.g., 2:1 or 3:2.

Fabrics of the invention may be made on looms such as Juergen's JP2000 or Jaeger's BK600, which have been fitted with a suitably high shaft capacity, or may be made on looms which utilize jacquard control over all or for some of the warp yarns.

A table showing preferred fabrics combinations and the required shafts is shown below. It can be seen that there are generally higher number of weave repeats when using the "high shaft" technique. This provides a significant benefit by allowing more randomness and flexibility in distributing binding points in composite fabrics and in distributing interchange points of interchanging yarn pairs employed in the fabric. In this way, a fabric with a reduced tendency to form undesired wiremarks in the formed paper sheet can be provided compared to the prior art.

No. of	No. of	Papersi de	No. of	No. of	Wearsi de	No. of	Ratio	
Loom	Papersi de	Weave	Papersi de	Wearsi de	Weave	Wearsi de	PS:WS	
Shaft	Warps		Weave	Warps		Weave	Weave	
			Repeat s			Repeat s	Repeat s	
20	10	Plain(1/ 1)	5	10	4/1	2	2.50	Prior Art
24	12	Plain(1/ 1)	6	12	5/1	2	3.00	Prior Art
24	12	2/1	4	12	5/1	2	2.00	Prior Art
28	14	Plain(1/ 1)	7	14	6/1	2	3.50	
28	14	Plain(1/ 1)	7	14	4/1/1/1	2	3.50	
30	15	2/1	5	15	4/1	3	1.67	
32	16	Plain(1/ 1)	8	16	3/1	4	2.00	
32	16	Plain(1/ 1)	8	16	7/1	2	4.00	

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32	16	Plain(1/ 1)	8	16	5/1/1/1	2	4.00	
36	18	Plain(1/ 1)	9	18	5/1	3	3.00	
36	18	2/1	6	18	5/1	3	2.00	
36	18	Plain(1/ 1)	9	18	8/1	2	4.50	
36	18	2/1	6	18	8/1	2	3.00	
40	20	Plain(1/ 1)	10	20	4/1	4	2.50	
40	20	Plain(1/ 1)	10	20	7/1/1/1	2	5.00	
40	20	2/2	5	20	9/1	2	2.50	
42	21	2/1	7	21	6/1	3	2.33	
48	24	1/1	12	24	7/1	3	4.00	
48	24	2/1	8	24	7/1	3	2.67	
48	24	2/1	8	24	5/1/1/1	3	2.67	
56	28	1/1	14	28	6/1	4	3.50	

It should be noted that in some of the identified high shaft fabrics having 28 shafts or more the number of weave repeats in the fabric cross-direction of the weft yarns with the warp yarns in the paper side layer within the repeat pattern of the composite fabric is greater than the number of weave repeats in the fabric cross-direction of the weft yarns with the warp yarns in the machine side layer within the repeat pattern of the composite fabric by a ratio of more than 3:1. The benefits of this feature will be described and claimed in a subsequently filed application.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1, illustrates transverse sectional views between each weft path in one repeat of a fabric in accordance with this invention; and

Fig. 2, illustrates transverse sectional views between each weft path in one repeat of a fabric in accordance with another embodiment of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

The weft paths of the paper side, wear side and interchanging yarn pairs for one preferred embodiment of a composite forming fabric 10 in accordance with this invention are shown in Fig. 1. In accordance with this embodiment, the composite forming fabric has a 20 shaft – 40 pick repeat and includes a paper side layer 12 having a paper side surface 14, a machine side layer 16 having a bottom wear side surface 18 and a plurality of first and second interchanging yarns pairs, e.g., 20.

The paper side layer 12 and the machine side layer 16 each comprise a plurality of warp yarns 22 in the machine direction and plurality of non-interchanging weft yarns 24 woven together with the warp yarns. The paper side layer 12 and the machine side layer 16 each have a predetermined repeat of the weave pattern in the cross-machine direction. As illustrated, but not by a way of limitation, the illustrated composite fabric 10 is a twenty (20) shed – forty (40) pick fabric including ten (10) machine direction warp yarns 22 in the paper side layer, shown at 1, 3, 5, 7, 9, 11, 13, 15, 17 and 19, and ten (10) machine direction warp yarns 22 in the machine side layer, show at 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20. The non-interchanging weft yarns in the paper side layer 12 are designated in Fig. 1 by the prefix "T" and the non-interchanging weft yarns in the machine side layer 16 are designated in Fig. 1 by the prefix "B."

As illustrated in Fig. 1, the first and second interchanging yarns of each pair of interchanging yarns are designated with the prefix "I"; a first pair being designated I1, I2; another pair being designated I3, I4, and so on. Each pair of interchanging yarns has two segments in the paper side layer within each repeat of the weave pattern. These segments provide an unbroken weft path in the paper side surface, with each succeeding segment being separated in the paper side surface of the paper side layer by

at least one paper side layer transitional warp yarn 22T (e.g., top warp yarns 5 and 13 are transitional warp yarns for interchanging binder yarns I9, I10). The pairs of interchanging yarns 20 move out of and into the paper side layer, respectively, on opposite sides of each transitional warp yarn. As is shown in Fig. 1, the interchanging yarns cross each other as they move in opposite directions in a region generally underlying the transitional warp yarns.

Still referring to Fig. 1, the fabric 10 of this invention includes a first set of alternating pairs of first and second interchanging yarns within each repeat of the weave pattern constituting binder yarn pairs 26 for binding together the paper side layer and machine side layer, i.e., I1-I2; I5-I6; I9-I10; I13-I14 and I17-I18. The fabric 10 also includes a second, alternating set of pairs of first and second interchanging yarns within each repeat of the weave pattern constituting top weft/binder yarn pairs 28 for stiffening the fabric and binding together the paper side layer and the machine side layer of the fabric. This second set of top weft/binder yarn pairs is shown at I3-I4; I7-I8; I11-I12; I15-I16 and I19-I20.

In the embodiment illustrated in Fig. 1, the top weft yarn in each of the top/weft binder yarn pairs floats between the paper side layer 12 and the machine side layer 16 to provide a stiffening function. In the embodiment illustrated in Fig. 1, the top weft yarn of each of the top weft/binder yarn pairs actually floats between five (5) sets of upper and lower warp yarns in the paper side layer and machine side layer, respectively, e.g., the top weft yarn in the top weft/binder yarn pair I3-I4 floats between adjacent upper and lower warp yarns 13-14; 15-16; 17-18; 19-20 and 1-2. Moreover, the binder yarn in each of the top weft/binder yarn pairs forms two knuckles in the paper side layer segment within each weave repeat, e.g., the binder yarn in the top weft/binder yarn pair I3-I4 forms knuckles over top warp yarns 15 and 19; the binder yarn in the top weft/binder yarn pair I7-I8 forms knuckles over top warp yarns 3 and 7; etc. As will be illustrated and explained below, both the float distance of the top weft yarn and the number of formed knuckles of the binder yarn in the paper side layer in top weft/binder yarn pairs can be varied within each repeat of the weave pattern.

Although in a preferred embodiment of the invention the binder yarn pairs and the weft/binder yarn pairs each constitute 50% of the interchanging yarn pairs in the fabric, in accordance with the broadest aspects of the invention, the percentage of interchanging yarn pairs provided by binder yarn pairs and top weft/binder yarn pairs cam be varied.

Moreover, it should be apparent that alternate unbroken weft paths are provided by the pairs of first and second interchanging yarns, which alternate with non-interchanging, top weft yarns that weave only with the warp yarns of the paper side layer. In other words, in the embodiment illustrated in Fig. 1, 50% of the weft yarn paths in the cross-machine direction of the paper side layer are provided by interchanging pairs of yarns, and the other 50% are provided by non-interchanging weft yarns that interweave solely with the warp yarns of the paper side layer.

Although, in the preferred embodiment at least some of the weft yarns in the paper side layer and in the machine side layer are non-interchanging yarns, i.e., they are disposed only in the paper side layer and the machine layer, respectively, in accordance with the broadest aspect of this invention the number of such non-interchanging weft yarns can be varied within wide limits. Additionally, the percentage of binder yarn pairs and top weft/binder yarn pairs also can be varied within wide limits and, if desired, may form all of the weft paths in the paper side layer.

In accordance with the preferred embodiment of the invention illustrated in Fig. 1, adjacent weft paths in the paper side layer are provided successively by a non-interchanging top weft yarn, a pair of interchanging binder yarn pairs, a non-interchanging top weft yarn and a pair of top weft/binder yarn pairs. These four weft paths repeat continuously throughout the fabric structure. In this latter arrangement, one-half of the weft yarn paths in the paper side layer fabric are provided by non-interchanging weft yarns; one-quarter of the weft yarn paths in the paper side layer are provided by binder yarns pairs and the other one-quarter of the weft yarn paths in the paper side layer are provided by weft/binder yarn pairs.

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It should be understood that the arrangement and percentage of each of the different weft yarns in the paper side layer can be varied within wide limits. In accordance with the broadest aspects of this invention, within each repeat of the weave pattern there is included at least one pair of first and second interchanging yarns in the form of a binder yarn pair and at least one pair of first and second interchanging yarns in the form of a top weft/binder yarn pair.

In accordance with the preferred embodiment of the invention illustrated in Fig. 1, 50% of the interchanging yarn pairs are binder yarn pairs and 50% of the interchanging yarn pairs are top weft/binder yarn pairs. However, it is within the scope of the invention to include a greater percentage of interchanging binder yarn pairs; thereby resulting in a reduction of the percentage of pairs of top weft/binder yarn pairs and/or non-interchanging top weft yarns. Alternatively, it is within the scope of this invention to include more than 50% interchanging yarn pairs as top weft/binder yarn pairs; resulting in a reduction in the percentage of interchanging binder yarn pairs and/or non-interchanging top weft yarns.

Referring to Fig. 2, an alternate embodiment of a fabric of this invention is indicated at 100. The fabric 100 has a number of features that are similar to the fabric 10. For example, the fabric 100, like the fabric 10 includes alternating, non-interchanging top weft yarns and interchanging yarn pairs. Also, every other interchanging yarn pair is a binder/binder pair and the other alternate interchanging yarn pairs are top weft/binder yarn pairs.

However, the fabric 100 has a 20 shaft – 80 pick repeat, unlike the 20 shaft – 20 pick repeat of the Fig. 1 embodiment. The increase in the pick repeat results from two variations in the weave pattern of the top weft/binder yarn pairs in the Fig. 2 embodiment.

First, in the fabric 100, the top weft yarn in adjacent top weft/binder yarn pairs float, respectively, between five (5) sets of upper and lower warp yarns and seven (7) sets of upper and lower warp yarns, e.g., the top weft yarn of the top weft yarn/binder yarn pair I3-I4 floats between the five (5) sets of upper and lower warp yarns 13-14, 15-16, 17-18, 19-20 and 1-2, and the top weft yarn of the adjacent top weft yarn/binder yarn pair I7-I8 floats between the seven (7) sets of upper and lower warp yarns 9-10, 11-12, 13-14, 15-16, 17-18, 19-20 and 1-2.

The second variation is that the binder yarn of adjacent top weft/ binder yarn pairs alternately forms two (2) paper side knuckles and three (3) paper side knuckles within each repeat of the weave pattern, e.g., the binder yarn in the top weft/binder yarn pair I3-I4 forms two (2) knuckles over top warp yarns 15 and 19, and the binder yarn in the adjacent top weft/ binder yarn pair I7-I8 forms three (3) knuckles over top warp yarns 11, 15 and 19, etc.

The above discussed two variations in the weave pattern of the top weft/binder yarn pairs accompanied by the fact that alternate top weft yarns are non-interchanging yarns and the alternate interchanging yarn pairs are bind/binder yarn pairs results in a repeat of the weave pattern every eighty (80) picks.

It is within the scope of the embodiment of the invention illustrated in Fig. 2 to make the same modifications as disclosed for the fabric 10. That is, the percentage of non-interchanging binder yarn pairs, the percentage of interchanging top weft/binder yarn pairs and the percentage of interchanging binder yarn pairs can be varied within wide limits. If desired the interchanging top weft/binder yarn pairs and interchanging binder yarn pairs can form all of the weft paths in the structure.

Applicant has determined that significant advantages may be obtained in the fabrics 10 and 100 of this invention, as compared to prior art structures in which all of the interchanging yarn pairs are binder/binder pairs. In particular prior art structures and the fabrics 10, 100 were formed with the warp and weft yarns being of the same diameter

and with the same number of warp and weft paths per unit area. The prior art structures included alternating weft paths formed by non-interchanging top weft yarns having a diameter of 0.13 mm and by interchanging binder/binder yarns with each yarn of the pair having a diameter of 0.13 mm. The fabrics 10 and 100 included alternating weft paths formed by non-interchanging top weft yarns having a diameter of 0.13 mm and by interchanging yarn pairs with each yarn of the pair having a diameter of 0.13 mm, wherein every other interchanging yarn pair was a bind/binder yarn pair and a top weft/binder yarn pair, respectively.

It was determined that the fabric 10 was approximately 17% stiffer and the fabric 100 was approximately 19% stiffer than the prior art structure.

It was determined that the fabrics 10 and 100 had a higher air permeability (cubic feet per minute), a greater thickness, or caliper (millimeters) and a higher void volume (cubic centimeters/square meter) than the prior art structure.

Although a higher air permeability and greater void volume may not be desirable, because of the possibility of greater water retention in the fabric, it should be understood that these higher permeability and void volume values were obtained in fabrics of this invention having the same concentration of warp and weft yarns as the prior art structure and with the warp and weft yarns having the same diameter as the prior art structure, and also without a significant reduction in fabric strength as compared to the prior art structure. Therefore, improved resistance to undesired water marks can be obtained in the fabrics of this invention by increasing the concentration of top weft and/or top warp yarns, and improvements in mechanical properties can be achieved by increasing the diameter of the bottom warp and/or weft yarns, while also achieving a reduction in air permeability and void volume to more desirable levels. Alternatively, it is possible to reduce yarn diameter in fabrics of the invention and still get identical CD stiffness to fabrics of the prior art but with reduced thickness.

In accordance with an additional embodiment of this invention (not illustrated), a composite forming fabric has the same construction as the forming fabric 10 or 100, with

the exception that one or more weft yarns, e.g., either non-interchanging weft yarns, interchanging binder/binder weft yarn pairs and/or interchanging top weft/binder yarn pairs, is (are) replaced with a fourth type of weft yarn system; namely, an intrinsic interchanging weft yarn/weft yarn pair. As explained earlier in the summary of the invention, an intrinsic interchanging weft yarn/weft yarn pair cooperates to provide a continuous weft path in the top fabric layer within each repeat of the weave pattern, just like the interchanging bind/binder yarn pairs and the interchanging top weft/binder yarn pairs. However, the yarns of the interchanging weft yarn/weft yarn pairs, when they drop out of the top surface adjacent a top warp transitional yarn, float between the top warp yarns and bottom warp yarns without binding to a bottom warp yarn.

In one embodiment employing weft yarn/weft yarn pairs, alternating weft paths in the paper side layer are provided by non-interchanging weft yarns, and located between each pair of these non-interchanging weft yarn paths is a binder yarn pair, a top weft/binder yarn pair and a weft yarn/weft yarn pair, respectively, in any desired order. As noted, in this embodiment one half of the weft paths are provided by non-interchanging top weft yarns; one-third of the weft paths provided by interchanging yarn pairs are provided by top weft/binder yarn pairs, one-third of the weft paths provided by interchanging yarn pairs are provided by weft yarn/binder yarn pairs and one-third of the weft paths provided by interchanging yarn pairs are provided by weft yarn/weft yarn pairs. However, in accordance with the broadest aspect of this invention, the percentages of each of the different types of interchanging yarn pairs can be varied within wide limits. In fact, in accordance with certain aspects of this invention, the composite forming fabric can include a single pair of first and second interchanging yarns in the form of weft yarn/weft yarn pairs, with the remaining interchanging yarn pairs being binder yarn pairs and/or weft/binder yarn pairs. Moreover, interchanging yarn pairs of the same or different type can be included adjacent to each other, in which case at least some of the adjacent non-interchanging top weft yarns will be spaced apart from each other by more than one interchanging yarn pair.

Embodiments of the invention including non-interchanging top weft yarns in the paper side layer; binder yarn pairs having segments in the paper side layer providing an

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unbroken weft path within each repeat of the weave pattern; top weft/top weft yarn pairs providing an unbroken weft path within each repeat of the weave pattern and weft yarn/binder yarn pairs providing an unbroken weft path with each repeat of the weave pattern have been described earlier herein. Suffice it to state that the form of the fabrics of this invention can include a combination of each of the four types of cross-machine direction weft yarns in the paper side layer. By varying the structure of the top weft path in the paper side layer to include different types of interchanging yarns and non-interchanging yarns, the overall properties of the forming fabric can be varied within wide limits, as dictated by the particular application of the fabric.

As should be noted in the fabrics 10 and 100, segments of one or more pairs of interchanging yarns can be of a different length within each repeat of the weave pattern. In accordance with the broadest aspects of this invention, the paper side segments provided by either all or some of the interchanging yarn pairs; whether such interchanging yarn pairs are binder yarn pairs, weft yarn/binder yarn pairs and/or weft yarn/weft yarn pairs, can be of different lengths.

In fabrics of the invention in which the yarns of each interchanging yarn pair provide segments of different length within each repeat of the weave pattern it is possible to vary the sequence in which the pair of yarns are placed in the fabric. For example, in a first pair of interchanging yarn pairs, the yarn providing the longest segment may be positioned prior to the other yarn of the pair, which provides the shortest segment. This arrangement may be reversed for the yarns of other interchanging yarn pairs throughout the fabric weave repeat. Furthermore, each interchanging yarn pair need not provide segments of the same length as other interchanging yarn pairs. In this case, it may be that the number of segments in some pairs of interchanging yarn pairs differs from the number of segments in other pairs of interchanging yarn pairs. This latter feature will be the subject of a separate patent application.

Various modifications can be made to the fabrics of this invention. For example, and not by way of limitation, the shape of the warp and weft yarns in both the paper side

layer and the machine side layer can be varied within the broadest aspects of the invention. As described earlier in the summary of the invention, it may be desirable to employ top warp yams having a dumbbell-shaped ("figure 8") cross-section, so that the two bulbous ends of each warp yam provide two support point for a fibrous web formed on the fabric. By increasing the number of support points for the web on the paper side layer of the fabric, a more planar forming surface is provided, which should achieve a more uniform formation of the fibrous web.

Other modifications include having one or more of the binder yams of interchanging binder yarn pairs and/or interchanging top weft/binder yam pairs bind to more than one bottom warp yarn. Such multiple bottom warp yams can be adjacent to each other or spaced-apart from each other. In either case the binding preferably takes place with bottom warp yams underlying top segments in which the other yarn of the pair is forming a portion of the top weft path.

Yet other modifications include the utilization of a weave other than a plain weave in the fabric papermaking layer. For example in a 24 shaft fabric of the invention a suitable paperside weave could be a 3 shaft twill.

Although the embodiments of the invention described in detail herein utilize CD orientated interchanging yarn pairs it is understood that within the broadest aspects of the invention MD orientated interchanging yarn pairs can be employed to bind and stiffen the fabric.

Without further elaboration, the foregoing will so fully illustrate our invention that others may, be applying current or future knowledge, readily adapt the same for use under various conditions of service.

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CLAIMS

What I claim as the invention is:

1. A composite forming fabric comprising a paper side layer having a paper side surface, a machine side layer having a bottom wear side surface, and a plurality of pairs of first and second interchanging yarns, wherein:
the paper side layer and the machine side layer each comprise warp yarns and weft yarns woven together;
said paper side layer and said machine side layer each having a predetermined repeat of the weave pattern in the cross-machine-direction;
each pair of first and second interchanging yarns having at least two segments in the paper side layer within each repeat of the weave pattern, said segments providing an unbroken weft path in the paper side surface, with each succeeding segment being separated in the paper side surface of the paper side layer by at least one paper side layer transitional warp yarn;
at least one pair of first and second interchanging yarns within each repeat of the weave pattern being binder yarn pairs, each binder yarn in each binder yarn pair binding together the paper side layer and the machine side layer, and
at least one pair of first and second interchanging yarns within each repeat of the weave pattern being top weft/binder yarn pairs for stiffening the fabric and binding together the paper side layer and the machine side layer of the fabric.

2. The composite forming fabric of claim 1, wherein at least 50% of the interchanging yarn pairs are binder yarn pairs.

3. The composite forming fabric of claim 1, wherein at least 50% of the interchanging yarn pairs are top weft/binder yarns pairs.

4. The composite forming fabric of claim 1, wherein at least one pair of first and second interchanging yarns is a weft yarn/weft yarn pair.

5. The composite forming fabric of claim 1, wherein a plurality of pairs of first and second interchanging yarns is weft yarn/weft yarn pairs.

6. The composite forming fabric of claim 2, wherein at least one pair of first and second interchanging yarns is a weft yarn/weft yarn pair.

7. The composite forming fabric of claim 2, wherein a plurality of pairs of first and second interchanging yarns is weft yarn/weft yarn pairs.

8. The composite forming fabric of claim 3, wherein at least one pair of first and second interchanging yarns is a weft yarn/weft yarn pair.

9. The composite forming fabric of claim 3, wherein a plurality of pairs of first and second interchanging yarns is weft yarn/weft yarn pairs.

10. The composite forming fabric of claim 1, wherein at least one of said at least two segments of at least one pair of first and second interchanging yarns has a different length than at least one other segment of said at least two segments of said at least one pair of first and second interchanging yarns.

11. The composite forming fabric of claim 1, wherein at least one of said at least two segments of each pair of first and second interchanging yarns has a different length that at least one other segment of said at least two segments of each pair of first and second interchanging yarns.

12. The composite forming fabric of claim 1, wherein at least some of the binder yarns in the pairs of first and second interchanging yarns float under at least two wear side machine direction yarns in a region underlying at least one of said at least two segments.

13. The composite forming fabric of claim 12, wherein said at least two wear side machine direction yarns are adjacent to each other.

14. The composite forming fabric of claim 12, wherein said at least two wear side machine direction yarns are spaced apart by at least one wear side machine direction yarn.

Figure 1

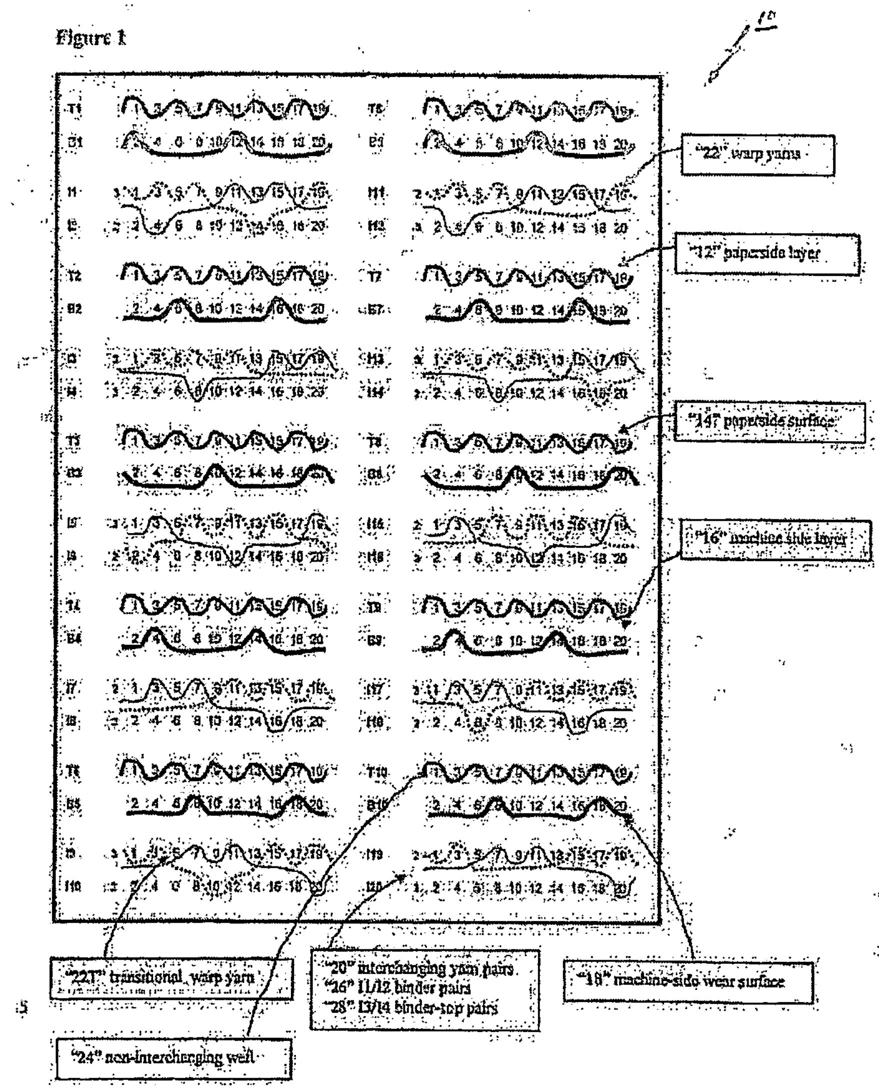
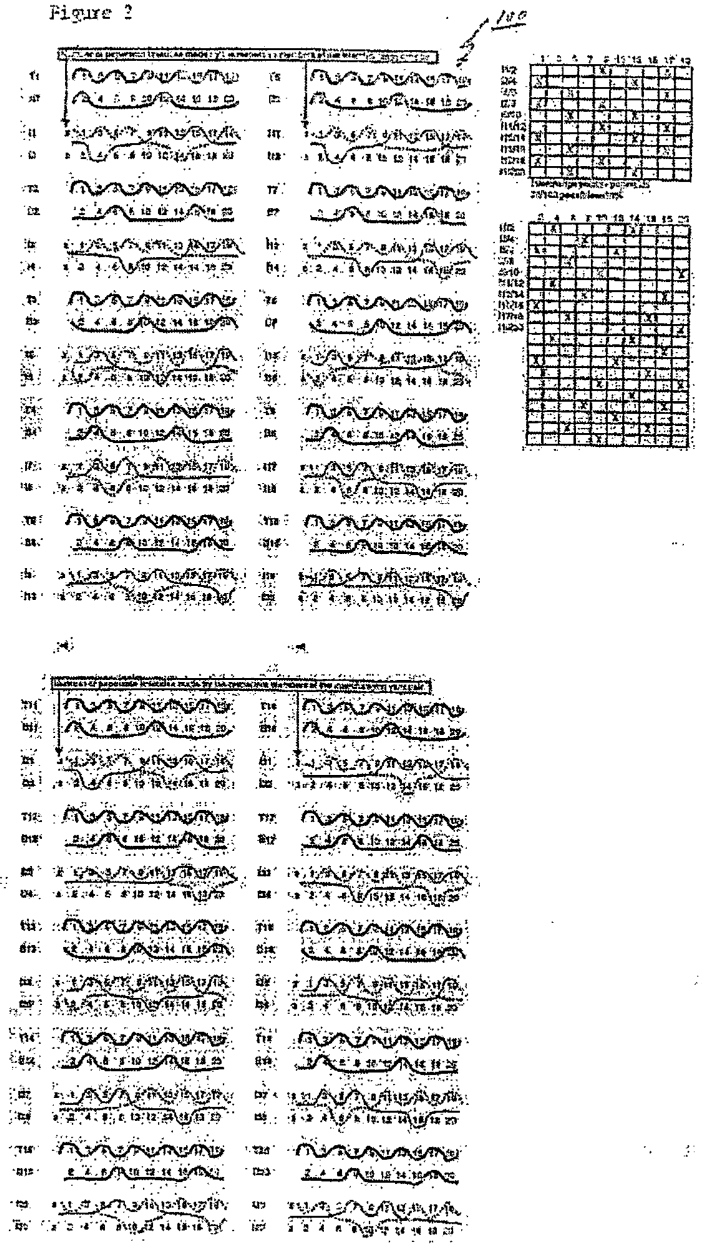

10
"22" warp yarns
"12" paperside layer
"14" paperside surface
"16" machine side layer
"22T" transitional warp yarn
"20" interchanging yarn pairs
"26" 11/12 binder pairs
"28" 13/14 binder-top pairs
"18" machine-side wear surface
"24" non-interchanging weft

Figure 2



INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP2004/050218

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 D21F1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 D21F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 152 326 A (VOEHRINGER FRITZ) 6 October 1992 (1992-10-06) cited in the application column 4, line 48 - column 5, line 63; figures 2-5	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 July 2004	26/07/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Helpiö, T.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP2004/050218

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5152326 A	06-10-1992	DE 3938159 A1	23-05-1991
		AT 107979 T	15-07-1994
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